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THE VERTICAL DRIER FOR SEED COTTON

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NEED FOR SEED-COTTON DRIERS

Plantations and cotton gins frequently lack facilities for storing seed cotton in quantities or for drying it artificially. Usually the first pickings require drying on account of the "green" condition of the cotton, while much of the late-picked cotton needs it because of dampness as a result of rains or fogs. Green or damp seed cotton is not only difficult to gin but the resulting lint is lower in quailty than that obtained from dry cotton. Any successful drying process must make it possible to handle cotton promptly after harvesting, whether from the early crop or from the late pickings.

The average modern gin in this country is equipped with four 80-saw stands and handles about 100 pounds of seed cotton per minute. However, a gin battery may vary from one to six or more stands. The process and equipment described in this bulletin have been worked out to provide a simple and dependable installation that will dry seed cotton continuously at a sufficient rate to prevent interruptions in ginning caused by wide variations of weather and of moisture content in the cotton. Provision has been made for capacity ample to supply all sizes of commercial ginning plants.

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The growing recognition of the benefit (*8*) [1] that may be derived from drying damp or wet seed cotton with the vertical seed-cotton drier developed by the United States Department of Agriculture (*1*, *2*) has resulted in a rapid increase in its use. The number of cotton driers in operation in the Cotton Belt increased from only 15 in 1931 to more than 1,300 in 1940. Eleven percent of the gins in the United States are now equipped with driers, and during each of the past three seasons gins equipped with driers have handled about 1 million bales of cotton.

Investigations to develop effective and economical means for drying damp seed cotton so as to make ginning easier were begun by engineers of the Department in 1926. Various types of apparatus were built and tested, including both horizontal and vertical drying chambers with trays or baskets on endless chains to carry the cotton and with belt or apron conveyors. A drier with a horizontal drying chamber 24 to 32 feet long with four to six sheet-metal floors along which the seed cotton was dragged by skeleton conveyors while exposed to a flow of heated air was found practical, but soon was succeeded by the vertical tower types described in this publication. In these types the drying chamber contains no moving parts, the seed cotton being carried through by the blast of drying air. Because of the simplicity of this design, it is more economical in construction and operation than the earlier types. Moreover, to an appreciable degree this type automatically adjusts the period of exposure in the drying chamber to the degree of dampness of the cotton, because cotton having little moisture weighs less and moves through the chamber more quickly than cotton having much moisture. This drier has proved satisfactory in actual service under wide variations in conditions.

THE GOVERNMENT PROCESS FOR DRYING SEED COTTON

In its investigations of means for artificially drying seed cotton, the United States Department of Agriculture developed and patented a process that has come to be known as the Government process, which may be used with several types of apparatus. This process involves the following features: (1) The damp seed cotton is treated with a continuous current of hot air, at the rate [2] of from 40 to 100 cubic feet of hot air for each pound; (2) the cotton is exposed to the drying process for different periods, usually from 15 seconds to 3 minutes, depending on the design of the drying apparatus; (3) the temperature of the drying air should be varied to resist the dampness and character of the cotton. Tests have proved that cotton can be dried satisfactorily with no unfavorable effects on the lint or on the planting quality of the cottonseed.

The temperature of the drying air should be carefully watched so no damage will be done to the staple. For the usual run of damp or wet cotton, the drying temperatures should not exceed 160° F. Preferably they should not exceed 150°. A slightly higher temperature can be used with very wet cotton, but under no circumstances should it exceed 200°. High temperature "bakes" the cotton, weakens

[1] Italic numbers in parentheses refer to Literature Cited, p. 30.

[2] BENNETT, CHAS. A. SIMPLIFIED PITOT TUBE CALCULATIONS OF AIR FLOW IN DUCTS AND PIPES. 4 pp., illus. [n. d.]. [Mimeographed.]

the fiber strength, and injures the spinning quality. It is better to pass wet cotton twice through a drier operated at a moderate temperature (150° F.) than once at a temperature above 200°. This slows down the rate of ginning, but many ginners do it to preserve the quality of the cotton.

This process of drying seed cotton is used successfully not only in the vertical drier designed by Department engineers and described in this publication, but also in other types of driers on the market.

In the experiments by which the Government process was developed it was found that to assure satisfactory ginning, the moisture content of the damp or wet seed cotton should be reduced to such an extent that the moisture in the lint would obtain ginning results like those produced by moisture in lint from seed cotton containing 8 to 12 percent moisture. In most cases this condition was obtained by removing about 3 pounds of moisture per 100 pounds of damp seed cotton. The experiment also showed heated air to be the most practical drying medium for this material.

Many variable factors influence the functioning of a cotton drier. Each design of drying apparatus produces individual drying effects, varying with the combination of influences of hot-blast volume, the period of exposure, and the temperature of the drying air as it enters the drier.

To meet the requirements of the process developed by the United States Department of Agriculture, a cotton drier should, (1) insure safety to fiber and seed, (2) treat uniformly all portions of the seed cotton from the first to the last of a load, (3) be adaptable to existing ginning plants without requiring special installation layouts for each gin, and (4) be so constructed that all parts are readily accessible, dependable, easy to operate, of ample capacity, and reasonable in cost.

CONSTRUCTION OF THE VERTICAL DRIER

The vertical driers described in this publication have no moving parts within the drying chamber and will readily dry cotton that does not contain an extraordinary amount of moisture. Wet cotton may be dried fairly well by passing it through the drier a second time. The apparatus will condition seed cotton for ginning in any kind of weather, provided the dried cotton is conveyed from the drier directly to the gins in the heated air. Various forms of installations are diagrammed in figures 1, 2, and 3.

The space required for the drier is not too great to permit installation in connection with cotton gins of standard widths and heights. The tower may be placed either within the gin buiiding or out of doors, as its construction is suitable for either location, but the steam coils, fans, and feeding equipment always are sheltered within the gin building so that they are accessible to the ginner at all times. As indicated in figure 1, the seed cotton is fed pneumatically through the wagon telescope to the separator that deposits the cotton in the hot blast created by the drier fan, which blows (or draws) air over heated coils. This hot air travels through the drying tower at approximately 800 to 1,200 linear feet per minute. The locks of cotton

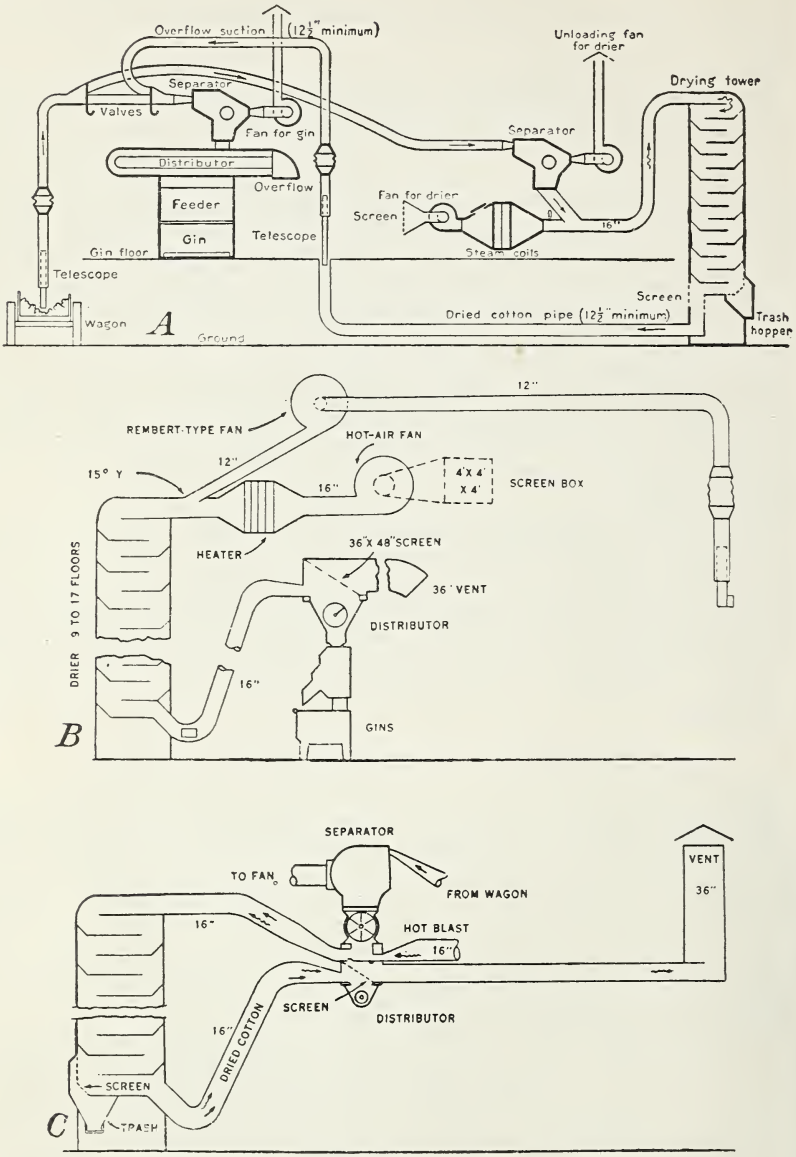


FIGURE 1.—Various forms of Government-design vertical driers now in use with either gravity or pressure delivery of dried cotton. *A*, Original Model A type, independent of ginning system, with two fans; *B*, wye system with Rembert-type fan; and *C*, blow-through system.

impinge violently upon the warm sheet-metal walls of the tower at each reversal of direction from floor to floor. From the bottom floor of the tower, the dried cotton is thrown against the cleaning screen where some of the foreign matter is cast out, after which the cotton is carried in an envelope of hot air to the gins. The following pages give details of construction by which most models can be built with the class of labor ordinarily available about cotton gins and plantations.

The tower may be installed either on the ground floor for suction or pressure delivery or above the ginning equipment in such a manner as to discharge the cotton into the distributor or the cleaning equipment by gravity as shown in figures 2 and 3.

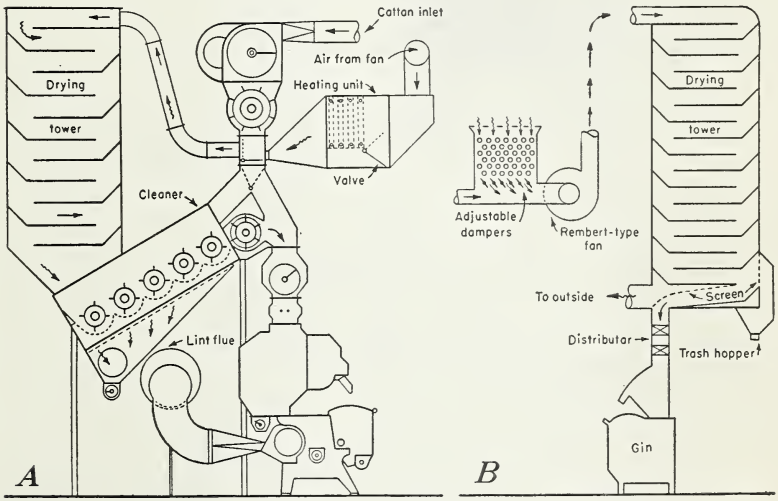
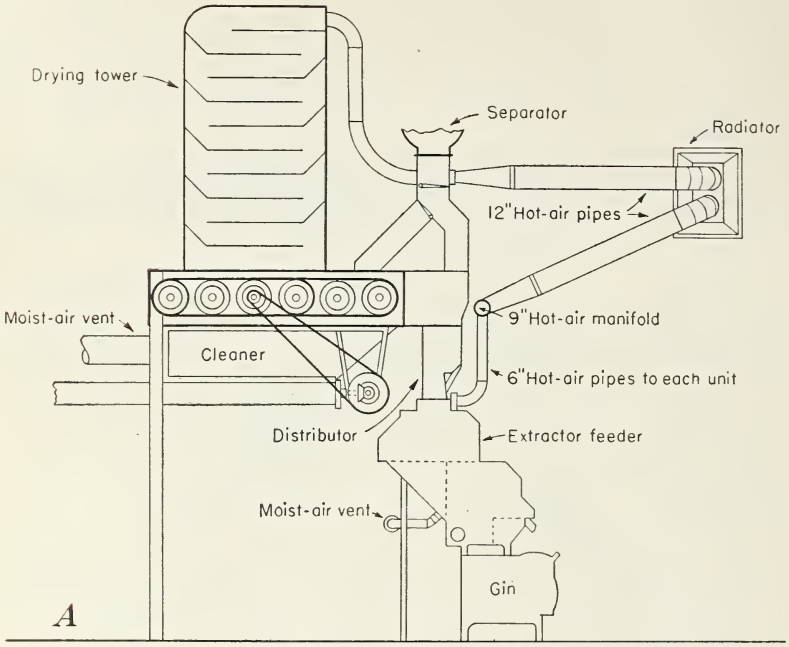


FIGURE 2.—Special forms of drier systems with elevated towers. *A*, Cross-blow supply and gravity discharge into cleaner; *B*, split suction, original Model B drier, with Rembert-type supply fan and gravity discharge into distributor.

Body construction details of the tower are the same for various installations but the top inlet and bottom outlet may differ as shown in figures 4 to 9. With the elevated-tower lay-out, the separator of the ginning system may, in many instances, serve the drier also, because the overflow of the gin does not need to be connected to the drier as must be done for the ground-level installation. An elevated tower is generally difficult to install in a two-story ginning plant because of the excessive height.

In the drying tower are 9 to 20 stationary sheet-metal floors carried on 2- by 4-inch wooden frames, or on light angle irons. In general, 17 floors provide ample exposure of the seed cotton to the drying process when unassisted by auxilliary cleaners or other apparatus. The number of floors may be less than 17 if the cotton to be handled is not too wet, or if the drying tower is combined with a



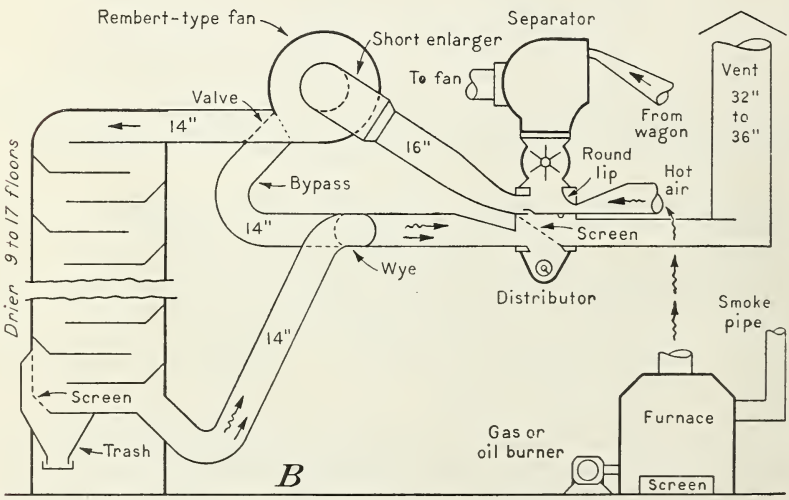


FIGURE 3.—Special forms of vertical drier installations. *A*, Combined with overhead-cleaner and extractor-feeder drier; and *B*, draw-through system with Rembert-type supply fan.

cleaner or feeder through which the drying process is continued. Where heavy fogs are prevalent, 19 or 20 floors may be advisable. Two floors more than the minimum necessary add but little to the cost. With an odd number of floors both top-inlet and bottom-outlet piping connections will be on the front of the drier; with an even number of floors the bottom outlet will be at the back of the tower.

The side walls of the tower are usually 4 feet apart and are lined with flat sheets of No. 28 galvanized iron and the floors are spaced

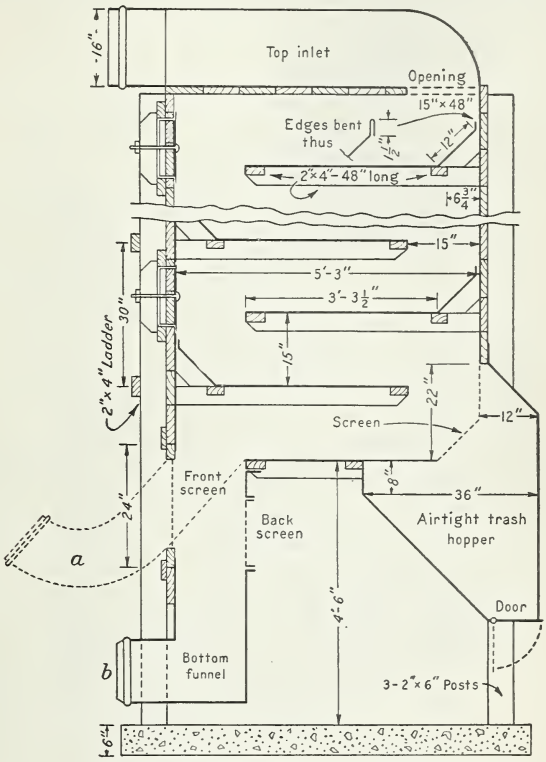


FIGURE 4.—Construction of details of tower. Vertical section with plain top inlet, showing bottom outlet (solid lines) for suctional gravity delivery and (dotted lines) for pressure delivery.

as shown in figure 4. The floors should be of No. 22 galvanized sheet iron or heavier. For the drier foundation, a concrete slab 7 feet long and 5 feet wide is desirable. Handholes should be placed in the front of the tower opposite alternate floors to permit access and inspection. Details of these handholes are shown in figure 7. A ladder on the front of the tower makes it easy to reach any handhole.

The details in figure 4 delineate spacing of the floors at 15 inches apart but this may be reduced to 11 or 12 inches where it becomes

necessary to save headroom or where it is desirable to utilize a low-tower drier in some one of the combinations shown in figures 1, 2, and 3.

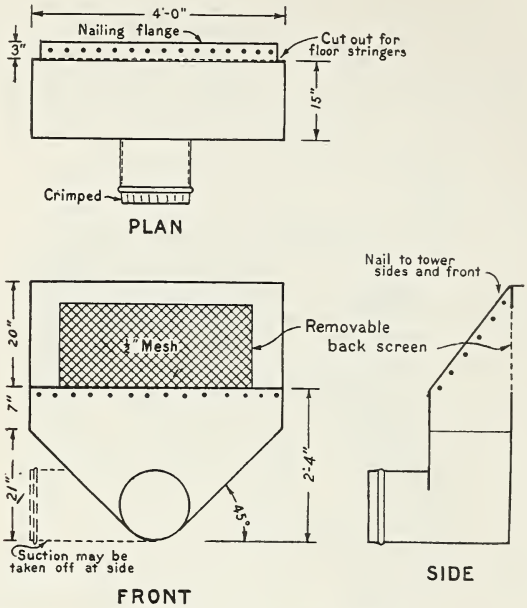


FIGURE 5.—Bottom funnel for suction take-off of dried cotton.

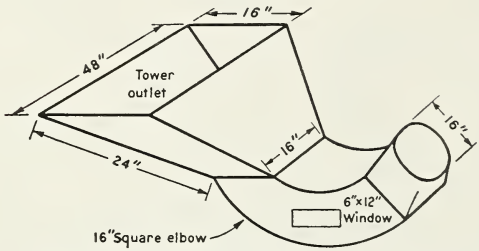


FIGURE 6.—Bottom funnel for pressure delivery of dried cotton.

Table 1 gives the height of towers, including the top inlet, for various numbers of floors.

TABLE 1.—*Height of towers, including top inlet for various numbers of floors*

Floors (number)	Spacing of floors	Total height of tower	
	Inches	*Feet*	*Inches*
9	15	16	3
9	12	14	0
11	15	19	6
11	12	16	0
13	15	22	1
17	15	27	1
20	15	30	10

An approximate bill of materials for a 17-floor tower is given in table 2. The plan dimensions of the tower are 5 feet 3 inches by 4 feet 0 inches, inside.

In constructing the tower for ground-level installation, it is frequently possible to build the front and back of the tower on the ground, complete with the handholes, and face them with galvanized sheet metal; then raise them to a vertical position and build up the sides. Usually the elevated tower, and sometimes the ground-level tower, must be built into place to suit the particular conditions.

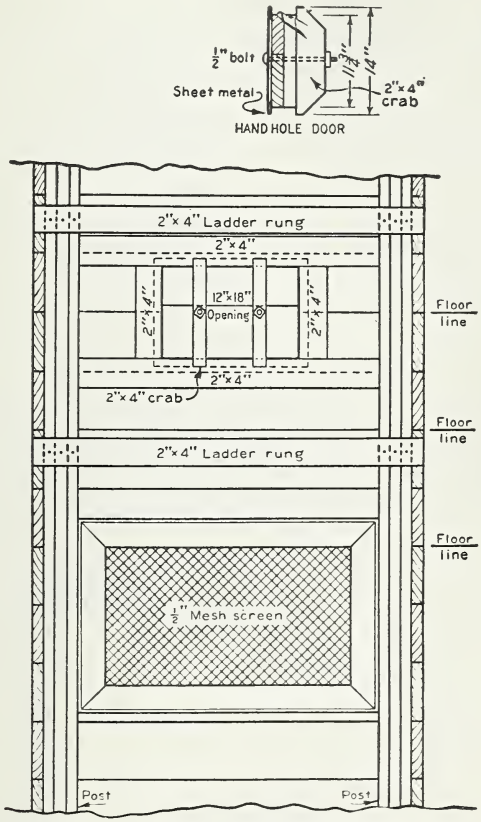


FIGURE 7.—Lower portion of front of tower, and handhole door, showing screen used with bottom funnel of figure 5.

The sills and crosspieces for the floors are usually built in as the side walls are built up. This is a very simple method of construction because planks can be placed on the floor frames to form scaffolding. The floor supports and incline pieces may be either spiked or bolted to the sides and ends of the tower, and the metal and floor incline sheets should be carefully nailed to them. The floors are laid and secured in turn, commencing with the lowest, and a top of 2-inch planking completes the carpentry work on the tower.

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All upper edges of the floor sheets and of the metal facing on the handholes should be beaded back into a return bend, having a round, smooth edge so that no cotton will be caught in passing through the drier. No nails smaller than eightpenny should be used in securing the galvanized lining and floor sheets, and where the nails go through the siding they should be clinched.

TABLE 2.—*Approximate bill of material for a 17-floor seed-cotton drying tower*

Description	Use	Quantity
Galvanized cotton piping, 16-inch and smaller	See drawings	(1)
Steam pipe, valves, etc	do	(1)
Sheet-metal top inlet	On top of tower	1
Sheet-metal bottom funnel	At bottom of tower	1
Fine intake screen	At steam coils	1
Heavy outlet screens, ½-inch mesh	At bottom of tower	2
2- by 6-inch by 14-foot yellow pine lumber	Corner posts of tower	24
2- by 8-inch by 14-foot yellow pine (to be cut)	Sides of tower	40
2- by 8-inch by 16-foot yellow pine (to be cut)	Front and back of tower	22
2- by 8-inch by 10-foot yellow pine (to be cut)	Top of tower	4
2- by 4-inch by 12-foot yellow pine (to be cut)	Ladder, etc	6
No. 28 galvanized plates, 48 by 96 inches	Front and back lining of tower	6
No. 28 galvanized plates, 48 by 72 inches	Lining sides of tower	12
No. 22 galvanized plates, 48 by 60 inches	Tower floors	17
½- or 7-inch carriage bolts and washers	Handholes in tower	16
2 by 4-inch by 4-foot yellow pine lumber	Floor supports	68
2- by 4-inch by 1-foot yellow pine lumber	Incline supports	34
Sixteenpenny common nails		(2)
Eightpenny common nails		(2)

[1] As required. [2] 1 keg.

The top of the tower is then fitted with the top inlet of No. 22 galvanized sheet steel, which forms the hood where the hot air and damp cotton are delivered into the drier, as shown in figure 8. The top inlet is flared out and increased in area to slow down the hot-air

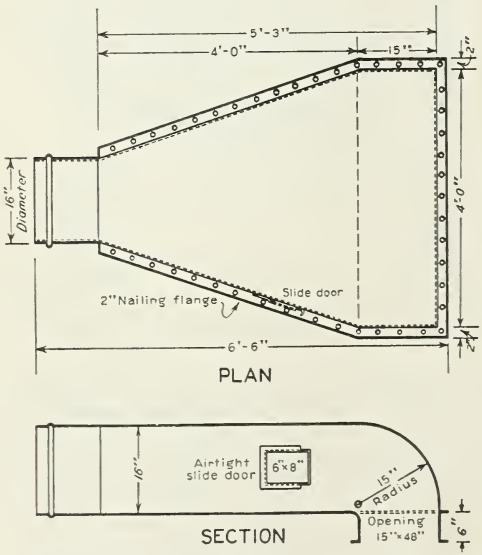

FIGURE 8.—Plan and section of plain top inlet for tower. This may be placed on the tower from either direction to suit.

currents so that their velocity will be just sufficient to carry the damp cotton from floor to floor, tumbling and drying it as it goes. The hot-air current keeps the cotton moving. A 1-inch steam line should be led to the 16-inch hot-blast pipe for use in gin fires. If the drier tower is exposed to the weather, it will be necessary to insulate and cover the top inlet to conserve heat.

After the floors have been secured in the tower, the bottom funnel should be nailed in position. Various shapes of funnels may be used; as shown in figures 5 and 6. The diameter of outlet for the gravity funnel may be varied to suit the gin suction, but is usually 12½ or 13 inches. Figures 5 and 6 show funnel constructions usually employed for the ground-level and pressure delivery towers. Where a low tower is placed upon an overhead cleaner the funnel is dispensed with, but where an elevated tower discharges by gravity into a belt or screw distributor, a special self-cleaning vent screen must be employed to carry the moisture-laden air and dust out of the gin building without inducing a flow of dusty air into the distributor along with the cotton.

The screens in the openings at the front and the back of the bottom funnel (figs. 4, 5, and 7) should be easily removable for access into the bottom funnel. They may be of perforated plate. In ground-level installations (figs. 1, *A*, and 2, *B*) they act as equalizers between the hot-blast fan of the drier and the regular suction fan of the gin, permitting a wide variation in the capacities of the fans and preventing a bottling or corking action in the tower. During operation of the drier, a great deal of pin trash and other dirt is thrown out through the front screen.

Still further effective and cheap cleaning of the seed cotton may be accomplished in the drier by introducing a screened trash hopper as shown in figure 4. With this cleaning feature built into the tower, ginners have been able to remove significant quantities of fine trash and other foreign matter, and frequently have employed the tower without heat in midseason ginning for its cleaning effect alone. The position indicated it suitable for this hopper, because there the seed cotton is in its driest and most fluffed-up condition. The hopper should be airtight and should be emptied at intervals as required.

VARIOUS FORMS OF INSTALLATION

Various successful forms of installations are in use as shown in figures 1, 2, and 3. The selection of any particular form should be influenced by the kind of gin building, the space available and the desired combinations with the ginning machinery.

Model A, Original Form of Drier

The standard two-fan drier installation, shown in figure 1, *A*, was developed concurrently with the invention of the vertical drier, and may be used with the gravity discharge as depicted for removing the dried cotton from the base of the tower by a pipe connection into which the regular gin overflow telescope may be plugged. The layout, however, is equally suitable for pressure delivery from the base

of the tower to storage bins or to a blow-box over a distributor or cleaner so that the drier may be operated independently of the main ginning system.

The suction fan on this model is usually a conventional size 35 or size 40 fan. For gravity delivery the drier fan on this model is usually size 35, running at 2,000 revolutions per minute, or size 40 fan running at 1,750 revolutions per minute; but these respective speeds should be stepped up to about 2,200 revolutions per minute for size 35 fan, and 1,900 revolutions per minute for the size 40 fan if pressure discharge at the base of the tower is to be used.

Split Suction Model B Form

The model B drier, shown in figure 2, *B*, is privately patented and will handle any moist cotton, but its manufacturers do not recommend it for snaps and bollies. The cotton from the wagon mixes with the hot air from the heater in the Rembert-type fan. The wagon suction and blast temperature are controlled by means of the dampers indicated and by valves on the heater. Satisfactory results can be obtained with this model if care is taken to maintain the drier inlet temperature slightly below that found desirable with the double-fan drier. The Rembert-type fan employed is usually a size 50–45 operating at speeds from 1,750 to 1,850 revolutions per minute.

Wye System With Rembert-Type Fan

The wye system form of drier installation (fig. 1, *B*) because of its increased volume, requires the same operating precautions as the system shown in figure 2, *B*. It has been used principally in the Mississippi River region in conjunction with Diesel-engine waste heat. It requires two fans of the same wheel diameter, but of different capacities—the narrow wheel operating on the hot-air branch and the wider wheel serving with the Rembert-type disk. The speed and volume characteristics of the two fans should be balanced to suit the pressure resistance of each individual system.

Although the plain top inlet depicted in figure 8 may be used with the conventional Y, the United States Cotton Ginning Laboratory has developed special improved top inlets which are shown in figure 9. These forms of inlet do not require so close a balancing of the fans as has been necessary with plain Y's. These improved inlets customarily employ a No. 30 drying fan (on steam radiators) and a No. 45–40 Rembert-type fan, both at speeds which may range from 1,400 to 1,890 revolutions per minute, depending upon the length of the cotton-suction pipe and the pressure resistance of the system. A No. 35 drying fan is suggested on Diesel waste-heat outfits to supply ample cooling air.

Single-Fan Blow-Through System

The model H blow-through system (fig. 1, *D*) is being used very successfully on ground level pressure-delivery and overhead towers (*4*) and may be connected with the regular separator of the ginning system in two ways, either as a cross-blow or parallel-blow arrange-

ment. Where the Government cross-blow method is used beneath the separator it is desirable to place the nozzle as close to the vacuum wheel as possible and to construct a rounded or deflecting lip on the

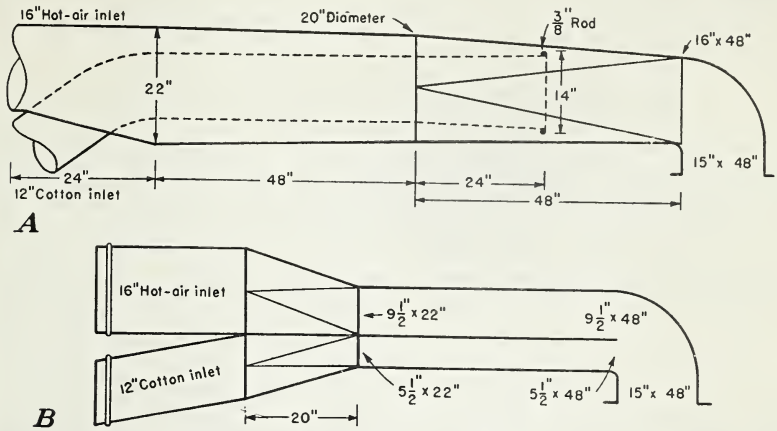

FIGURE 9.—Details of special top inlets for Y-system driers. *A*, Injector-type[3] top; and *B*, uniform expansion or shelf-type top.

upper edge of the inlet so that a smooth jet without eddies or cavitations is obtained for removal of the cotton from beneath the wheel. A successful form of cross-blow jet is detailed in figure 10.

The area of the cross-blow jet should not exceed 200 square inches, and the converging discharge funnel should be as long as the avail-

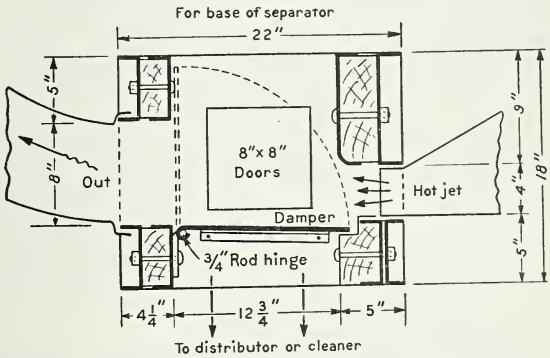

FIGURE 10.—Detail of cross-blow jet showing upper lip, bypass damper, and converging discharge funnel.

able space will permit so that the conveying jet of air will smoothly convey the cotton from the hopper to the tower inlet pipe.

For overhead towers with narrow floors spaced 11 or 12 inches apart, the drying volume of air may be supplied to the jet through a 14-inch pipe. A volume of 4,800 cubic feet of hot air per minute

[3] Suggested by Howard Stovall, and developed by the U. S. Cotton Ginning Laboratory.

through a 14-inch pipe is generally adequate, but where conventional 15-inch floor spacing is used it is desirable to have a 16-inch supply pipe for a volume of 5,500 or more cubic feet of air per minute passing through the body of the drying tower. If the suction pipe to the cotton fan gets hot it indicates that the vacuum wheel to the separator is leaking and that the wiper blades should be overhauled.

Rembert-Type Fan Draw-Through System

The United States Cotton Ginning Laboratory has developed an improved method for installing driers in old gins by introducing the Rembert-type fan draw-through system shown in figure 3, *B*. This method of drying is especially adaptable to small cotton gins because it may utilize any of the sources of heat and may even be employed with existing wooden separators, provided they have a reasonably good vacuum wheel. Additional advantages of this form of drier are their freedom from chokage below the separator, and in the fluffing-up action as the cotton strikes the disk of the Rembert-type fan, which materially enhances the effectiveness of the drying throughout the entire length of the tower. This system is also very convenient because the Rembert fan may usually be placed above the main shaft of the gin in alinement with the base of the separator, thereby simplifying the suction pipe for the drier to a minimum. In several successful installations of this kind, a low-tower drier has been placed directly behind the gin stands on long legs on the gin floor so that it will not interfere with the lint flue, and the discharge from the base of the tower has been delivered under the conveying air pressure to a screened blow-box which is placed directly beneath the dropper box so that the cotton is returned to the same point. Suitable by-pass valves and a fan-suction cut-off may be constructed to operate from one level so that dried cotton from the gin overflow need not be passed through the tower a second time.

Screened blow boxes over screw distributors may produce objectionable dust unless properly constructed, vented, and in certain cases, supplied with a sealed dropper wheel. Both new and second-hand suction separators have been successfully converted into dust-proof blow boxes by removing the beating reels and adjusting the vacuum wheel-wiper blades to make a minimum contact with negligible friction. The combined action of the Rembert-type fan and the screened return-blow box or a screen in the bottom of the tower provide a very satisfactory cleaning action.

The size of Rembert fan customarily employed with this system is a No. 45–40, operating at a speed of 2,000 or more revolutions per minute, delivering approximately 5,000 cubic feet of hot air per minute into the body of the tower. If the floors are spaced at 11 or 12 inches in the tower, 14-inch hot air suction and delivery pipes may be employed, but a 16-inch discharge pipe between the base of the tower and the return point to the system is recommended. If a 17-floor standard tower is used in connection with this system it is recommended that 16-inch pipe be used throughout.

The application of this draw-through system to Diesel waste-heat generators requires a speed of the Rembert-type fan that will pull

at least 5,000 cubic feet of cold air per minute through the engine radiator. To do this, the speed of a No. 45–40 flat-disk Rembert-type fan must be increased to approximately 2,300 revolutions per minute.

Combination Overhead Low-Tower and Cleaner Drier

For best results a combination tower and cleaner drier is recommended in factory construction because the manufacturer can combine them in the most satisfactory manner and make the best connections to the base of the ginning separator. This system is in satisfactory use in all parts of the Cotton Belt. One form of this combination method is shown in figure 2,*A*. Other installations (not shown) are making use of horizontal cleaners with similar satisfactory results.

The hot-air fan for this system should supply 4,800 to 5,500 or more cubic feet of air per minute and may utilize a No. 35 fan at about 1,900 revolutions per minute.

Duplex Overhead Low-Tower and Extractor-Feeder Drier

The duplex overhead low-tower and extractor-feeder drier, (fig. 3, *A*), is a recent development in the field of cotton drying, and permits a desirable initial drying, precleaning, and fluffing-up of the cotton before introducing it into the extractor feeder for final conditioning. Either or both of the drying applications may be employed, depending upon the moisture content of the cotton and other seasonal elements. The volume of air required for the tower portion of the drier is usually greater than that necessary in the extractor feeder, and is proportioned at approximately 4,200 cubic feet per minute for the tower plus 700 cubic feet per minute for each unit extractor feeder. It may be minimized by spacing the floors of the tower at 11 inches, and by further reducing the volumes into the extractor feeders. Under usual conditions of operation on a 4–80 outfit, a volume of approximately 7,000 or more cubic feet of air per minute is obtained with a No. 45 or larger fan at about 1,900 revolutions per minute. Although this method uses the Government design of vertical drier, the combination here shown is made with a privately patented system and the apparatus is therefore available in a complete factory-made unit.

AIR VOLUME

For preliminary use in selecting fans for the drier installations which have been described, the quantities of heated air required to remove 3 pounds of moisture per 100 pounds of seed cotton having an initial moisture content of 12 percent or more may be taken as shown in the following tabulation. These quantities have been calculated for atmospheric conditions of 70° F. temperature and 75 percent relative humidity and a drier efficiency of 45 percent.

Temperature of air entering drier (°F.):	*Volume of air entering drier per minute (Cubic Feet)*
140	6,100
150	5,300
160	4,850

In Missouri, Tennessee, and northern Arkansas the late-season cottons frequently contain whole bolls, both green and otherwise. Where such unopened cotton bolls are to be handled it is necessary to use some form of boll breaker in conjunction with the drier system in order to adequately dry such material.

COTTON PIPING AND FAN POWER

Tightness of cotton piping joints and valves is a basic requirement for the most successful and economical operation of vertical driers. Direct runs with minimum turns and lengths of piping are essential to their simplicity and low cost.

Drier fan intakes, except Rembert-type, should be provided with screened cone inlets and volume control valves. The screen should be removable and of fine mesh wire if fin-type steam heaters are to be used, so that fly and fiber may not build up a mat on the surface of the coils. The valve permits a safe selection of pulleys and extra capacity until the volume has been adjusted to the satisfactory minimum consistent with good operation and economy. On the draw-through drier (fig. 3, *B*) a screen is desirable to protect the heater intake and a valve may be placed between the heater and dropper box for further volume regulation. To reduce the hazard of seed cracking, the intake pipe on Rembert-type fans should be slightly larger than the main runs of cotton conveying pipe and so proportioned as not to exceed an entrance velocity of 4,000 feet per minute into the fan.

To conserve heat all cotton piping leading to and from the drier should be insulated with common sheet asbestos or corrugated paper boxboard.

With driers whose separators drop seed cotton into a pipe parallel to the axis of the separator, a suction heel should protrude about 3 inches into the hot-blast pipe (fig. 1, *A*) as this tends to draw the cotton out of the separator and avoids chokage where the cotton enters the pipe.

From experience it has been found desirable to use either 14- or 16-inch piping from the drier fan to the tower, and 16-inch pipe for pressure delivery from the base of the tower to point of discharge. Although the 14-inch size obtains a higher conveying velocity in the main runs at less first cost, the 16-inch size offers much less pressure resistance (*3*) and is desirable on full-length towers or long runs in order to reduce the fan speeds and operating cost. An air velocity between 4,000 and 4,500 feet per minute is usually desirable for handling heavy seed cotton. At these suggested velocities the selection of the fan size and speed should be made with a view to delivering into the drier 4,800 or more cubic feet of air per minute through a 14-inch pipe, and 5,500 or more cubic feet through a 16-inch pipe.

All cotton gins are subjected to fire hazards. Bypasses and protective devices are therefore desirable for all drying systems to fight gin-fire hazard and also to prevent excessive drying of dried cotton from the gin overflow. If the temperature of the drying air cannot be quickly reduced, repeated passages through the tower with hot

air should be avoided. The bypass valve shown in fig. 3, *B*, accomplishes the latter object.

For continued use of the drying tower on overflow cotton there are two successful methods now in use as shown in figure 11.

A quick reduction in air temperature on Diesel engine waste-heat outfits (fig. 11, *A*) does not affect the cooling water of the engine but cuts out the exhaust heat when the gin overflow is being handled. On steam coils (fig. 7, *B*) the use of a mixing and bypass damper obtains a quick adjustment in temperature with simplicity.

Pressure resistances of drying systems may range from 8 to 14 inches water gage, an average for 16 typical installations being 12.4 inches. This includes pressure losses through fan intake, heater, tower, delivery funnel, blow box, and all piping.

Within this range of resistance pressures, the fan speed for different sizes of fans may be selected from the performance tables of

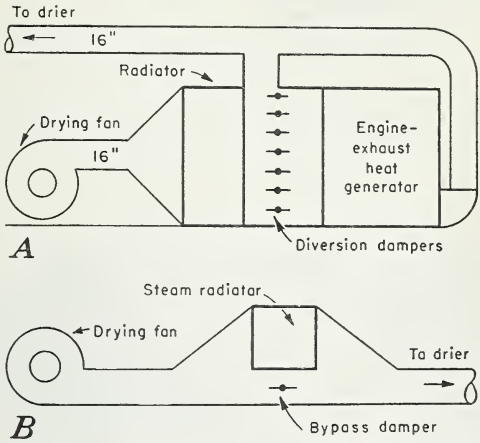

FIGURE 11.—Temperature-reduction method for protective adjustments of drying air volumes: *A*, Engine-waste-heat diverter; and *B*, steam-radiator bypass damper. When dampers are closed (*A*) the exhaust section of generator is bypassed.

fan manufacturers. Table 3 gives volume and horsepower for these ranges, so that fan selection may be simplified.

Where a cotton-drying fan draws air through a heater and thence into the fan, it is necessary to increase its speed between 15 and 20 percent over that required for cold air, in order to compensate for the air expansion resulting from heating.

Fans for driers may have 6- or 8-blade plain or 18-blade type C (cupped blade) wheels. The plain wheels are usually 32 inches in diameter, with varying widths in proportion to capacity, but the type C wheels have diameters averaging 23, 26, and 30 inches for nominal-size fans Nos. 35, 40, and 45 respectively. Table 3 gives the average speed for the first two sizes of both kinds of fans, as they apply to the average pressure resistances of vertical drier systems.

TABLE 3.—*Fan horsepower, volumes, and fan speeds for vertical-drier systems operating at different resistance pressures* [1]

Air volume before heating (cubic feet per minute)	Approximate fan horsepower at different water gage resistances [2]				Average fan speeds [3] for 12-inch static pressure				
	8-inch static pressure	10-inch static pressure	12-inch static pressure [5]	14-inch static pressure	8-blade plain wheel		18-blade C wheel		Speeds for Rembert-type fan [4] size 45–40
					Size 35	Size 40	Size 35	Size 40	
	Horsepower	*Horsepower*	*Horsepower*	*Horsepower*	*Revolutions per minute*	*Revolutions per minute*	*Revolutions per minute*	*Revolutions per minute*	*Revolutions per minute*
4,800	13	15	17	19	1,595	1,525	1,810	1,680	2,000
5,500	16	18	21	24	1,645	1,565	1,900	1,760	2,300
6,300	20	23	26	29	1,700	1,620	2,000	1,840	----------

[1] Given as "Static pressures" or "S. P." in commercial tables.
[2] For type C wheels only. Add 10 percent for plain wheels. Does not include separator power and losses.
[3] Computed from tests and performance tables.
[4] From tests on draw-through (fig. 3-B) driers with pressure delivery, showing 6-inch static pressure across fan.
[5] Use of this average static pressure is suggested for fan selection on blow-through driers.

Two Rembert-types of fans are used in vertical-drier installations, depending upon the methods of handling seed cotton. Rembert-type fans, which handle the seed cotton directly through their casings, are shown in figure 12. The flat disk fan (fig. 12, *A*) is of relatively low efficiency and will crack seed if dry cotton enters the wheel at air

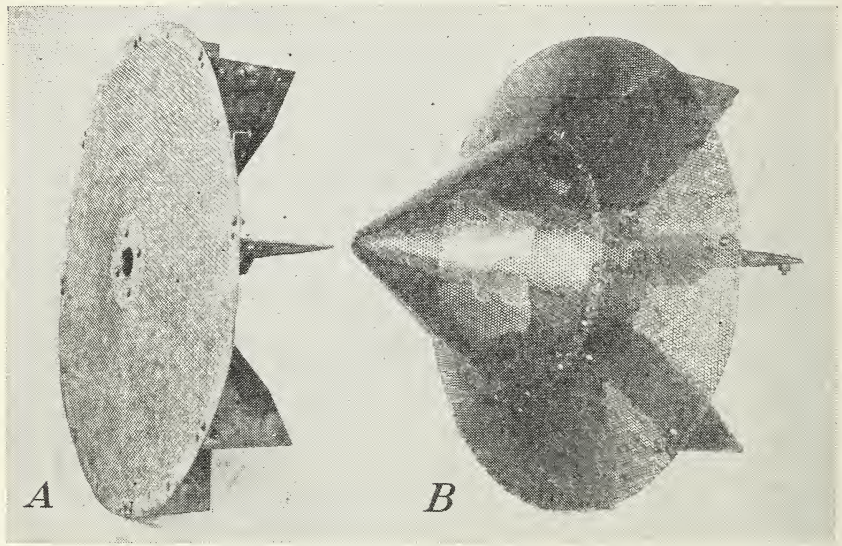

FIGURE 12.—Examples of Rembert-type fan wheels: *A*, Conventional flat-disk low efficiency wheel; *B*, improved compound cone wheel developed at the United States Cotton Ginning Laboratory.

velocities above 4,000 cubic feet per minute. The compound cone fan [4] (fig. 12, *B*) is more efficient and will not begin to crack seed until air velocities exceed 4,500 cubic feet per minute. It was developed at the United States Cotton Ginning Laboratory.

[4] Dedicated patent No. 2,225,397, issued Dec. 17, 1940.

SOURCES OF HEAT

Rapid developments in methods of installing tower driers have led to the use of a number of satisfactory sources of heat (*7*) and collateral safety precautions in operating them.

Hot-Air Furnaces

Hot-air furnaces, preferably of welded construction for tightness are available on the market for the driers shown in figure 1, *B*, 1, *C;* and 3, *B*. Heating capacities, ranging from 400,000 to 700,000 British thermal units [5] rating, should be selected. A normal capacity of 600,000 or more British thermal units should be adequate for all average installations serving 4 gin stands or more.

Air-tight, insulated jackets or masonary enclosures are necessary on furnace installations for conservation of heat and protection against fire. Screened intakes are essential on fans which supply such furnaces, and in case of draw-through systems, removable fine screen intakes should be installed with a view to accessibility and ready cleaning. The furnace may be constructed of cast iron or in conventional sheet-metal-drum form customary for halls and buildings, or they may be of tubular design. Tubular furnaces require tube-sheet protection so that direct flames may not strike or damage ends of the tubes projecting into combustion spaces.

Insurance requirements vary somewhat in different localities, and the location of the furnace should conform to the local rules.

Coal, wood, gin trash, and other fuels are being used as fuel for cotton-drier furnaces. Some furnaces are constructed for use with oil burners, and these afford many advantages in being ready for instant use without continual attention. Operation of all types of furnaces requires provisions for reducing the heat during those periods when the flow of air is cut off for any reason.

Direct-Fired Heaters

Gas-fired heaters employing natural gas, artificial gas, and gas generated from butane are being satisfactorily used for tower driers. Draw-through driers (fig. 3, *B*), and duplex systems, (fig. 3, *A*) have been particularly successful with direct-fired heaters.

Three commercial forms of direct-fired heaters are shown in figure 13.

Their capacities range from 500,000 to 1,000,000 British thermal units per hour, and they may be purchased for manual operation or with full automatic controls.

Engine Waste-Heat Recovery

For cotton gins having internal-combustion engines, manufacturers have developed means for utilizing waste heat from the engine cooling water and exhaust gases for cotton drying in conjunction with the vertical drier. (*5*, *6*.)

[5] A British thermal unit is the quantity of heat required to raise the temperature of 1 pound of water 1° F.

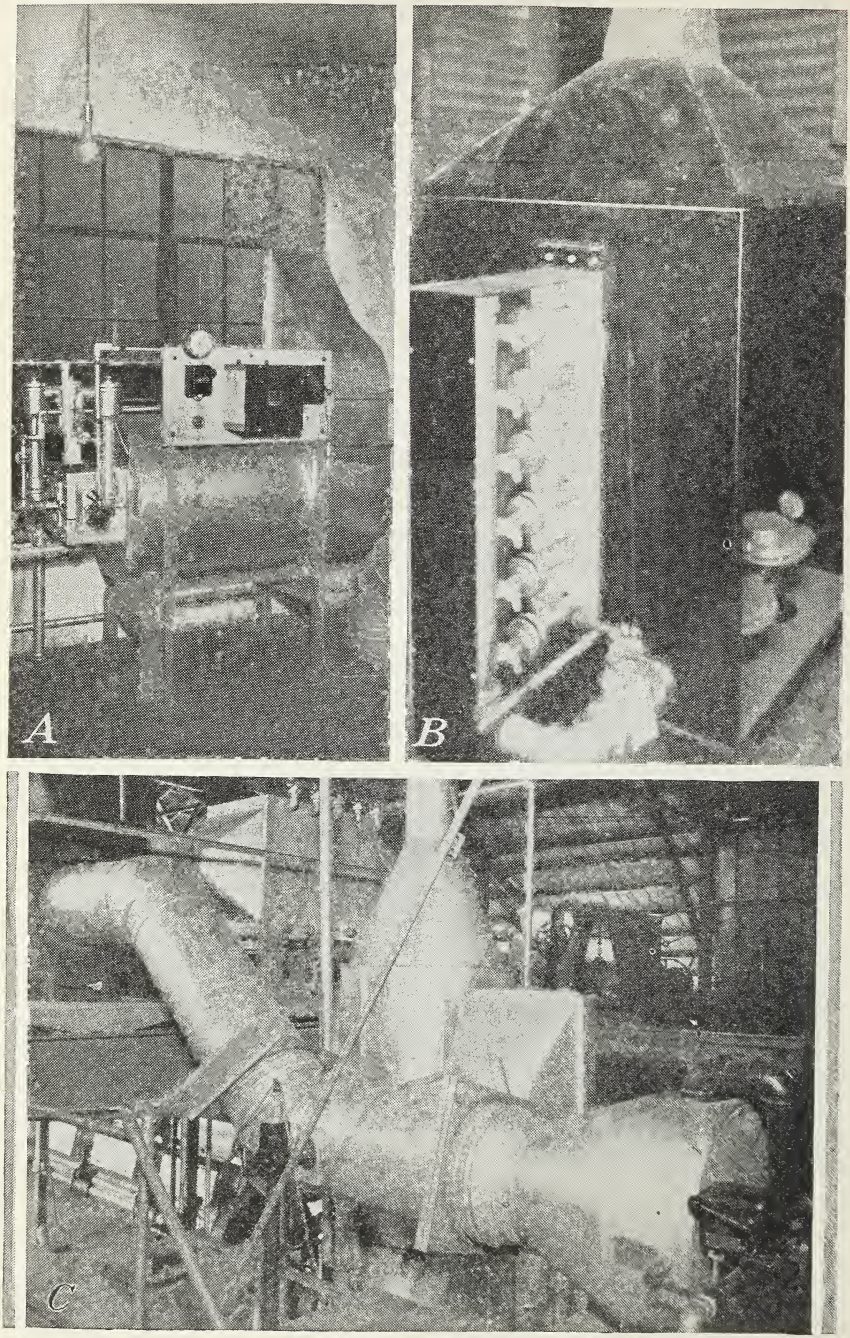

FIGURE 13.—Three types of direct-fired gas heaters used for cotton driers. *A*, horizontal cylindrical single-nozzle burner; *B*, multiple-burner type with central manifold and branches for individual jets; and *C*, ring-type, premixing burner requiring an auxiliary air pressure line for smokeless combustion.

The heat recovered from the cooling water and exhaust of these engines is approximately 2,900 heat units per hour per developed horsepower of the engine load, and in engines of over 100 horsepower should provide two-thirds or more of the heat needed for cotton drying. Supplementary furnaces or steam coils may be used to bring up the total supply for the drier to approximately 600,000 heat units per hour. Figure 14 shows the arrangement diagrammatically.

Sturdy and well-braced construction must be used in such heat generators to withstand vibration and the hazards of opened seams or joints which might introduce sparks and combustible gases into the drying system.

The cooling water radiators should have a nominal surface equivalent to 1,280 square feet of steam radiation for Diesel engines up to 150 horsepower, and 5,000 or more cubic feet of cooling air are required per minute. Thus, the actual net heating surface of these radiators should be 320 square feet or more, requiring four rows

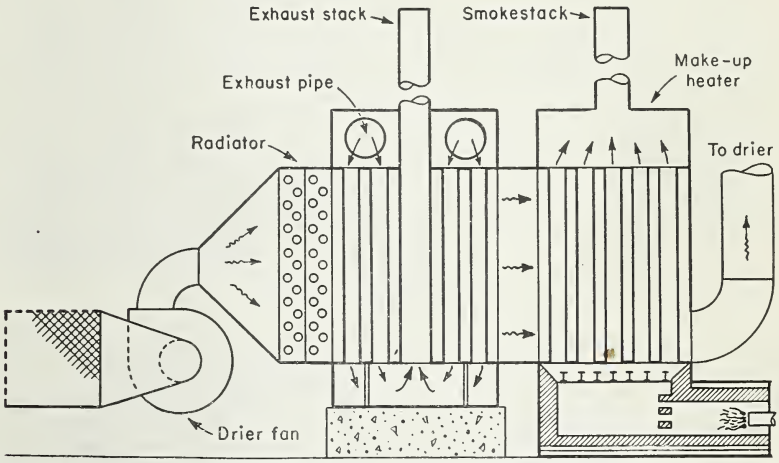

FIGURE 14.—Diagram showing complete system of waste-heat recovery for drying cotton.

deep of 30-inch by 60-inch commercial fin-type radiation. When steam plants are converted to Diesel power for cotton gins, the cotton-drying radiation units are frequently suitable for use as the engine radiator, especially if they have been proportioned for use with Government-designed vertical driers.

Details of construction of a conventional engine waste-heat recovery unit are shown in figure 15.

STEAM HEATERS

A 30-horsepower or larger steam boiler may be used for normal drying work, vertical boilers being preferred. Smaller coal-burning boilers have often been converted to oil burners, resulting in an increased capacity which has proved satisfactory for cotton drying. Pressure should be kept at from 50 to 100 pounds gage, and the boiler should be well covered to obtain economy of fuel. The steam coils

for the drier must be placed several feet above the water line of the boiler if the condensed steam is to drain back to the boiler without traps or pumps. A check valve should be put in the return line, and a ½-inch vent valve on each coil so that the heater will not become air-bound. Each coil vent may be led through a check valve to a common automatic vent valve, but the vents from two or more sections should not be combined without the use of check valves.

Where the ginning system is operated by steam power, it is frequently feasible to utilize the low-pressure exhaust steam for the heater coils of the drier rather than incur the expense of installing an additional high-pressure boiler. To do this requires increasing the size of

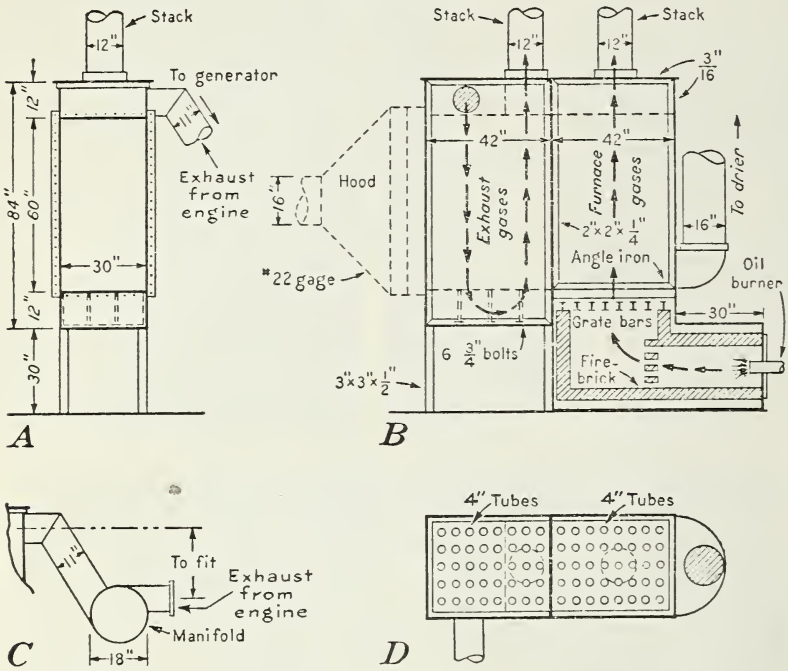

FIGURE 15.—Construction details of waste-heat recovery generator and furnace. *A*, Elevation at air-inlet end, with radiator removed; *B*, sectional elevations (tubes omitted), showing how exhaust and furnace gas travel; *C*, equalizer manifold to dampen engine exhaust vibrations; and *D*, tube-sheet plan of exhaust and furnace sections.

the heater by adding 20 percent more heating surface, and making certain changes in the piping systems to prevent restriction of the engine exhaust. The steam header for supplying low-pressure exhaust steam to the heater coils should be 4 inches or larger, and should be provided with a standard type of back-pressure or atmospheric exhaust valve that will not allow excessive back-pressure to be placed upon the engine exhaust. This back pressure may be adjusted to maintain 5 pounds of steam pressure or even less for cotton-drying purposes. A small valved supply pipe from the high-pressure steam piping of the boiler is desirable in order to supply additional quantities of steam to the exhaust line when necessary. For continual use, however, a re-

ducing valve should be employed. The use of exhaust steam in combination with the drying installations shown in figure 1 results in practical and cheaply operated driers for a steam-powered gin.

There are certain basic requirements of a heater for seed-cotton driers, which differ from those of heaters for other purposes because cotton driers are frequently forced to operate under a wide range of atmospheric conditions and because the air which must be handled by the heater is often charged with dust, cotton fibers, and other foreign matter. Enough heating surface must be provided to offset the decrease in efficiency when the heating elements have become clogged with foreign matter, but not enough to cause excessive temperature when the surfaces are clean or when steam pressures are increased. The volume of air to be handled by a heater depends to some extent on the method of feeding the drier (figs. 2 and 3) and the temperature of the air leaving the heater is affected by the temperature of the entering air, the working steam pressure, and the amount of dirt on the heating surfaces.

Well-established design practices favor limiting the velocity of air passing through an iron-pipe heater for seed-cotton drying to approximately 800 cubic feet per minute. Therefore, to handle approximately 5,000 cubic feet per minute as required for figures 1, *A*, and 3, *A*, installations, a heater should have 5 to 6 square feet of free area. For figures 1, *B*, and 2, *B*, somewhat smaller volumes are to be heated to a higher temperature than for the driers shown in figures 1, *A*, and 1, *C*, because they are diluted with unheated air from the wagon telescope and slightly larger heaters are therefore employed.

Iron-Pipe Heaters

Heat transmission per square foot of heating surface in iron-pipe heaters, with air velocities of 800 feet per minute, has been found in commercial tests to range between 6½ and 10 British thermal units per hour per degree difference between the temperatures of the steam in the heater pipes and the air flowing through the heater. New heaters are more efficient than those which have become dirty, rusted, or encrusted with foreign matter, but it has been found that a coefficient of transmission of 7½ British thermal units is dependable for cotton-drying calculations based on the entrance temperature of the air.

The load imposed upon the steam boiler by the heater for a seed-cotton drier seldom exceeds 600,000 British thermal units per hour, especially when the condensation is returned directly to the boiler. With customary steam pressures of 100 pounds gage (temperature 337.9° F.) and the coefficient of transmission of 7½, the heating surface, *S*, required for the heater with air entering at 60°, may be calculated as

$$S=\frac{600{,}000}{7\frac{1}{2}\times(337.9-60)}=288 \text{ square feet}$$

A welded iron-pipe heating unit that may be either factory-made or home-made is shown in figure 16. This unit is 2 rows deep and has 38 square feet of effective heating surface. Eight of these

units with 304 square feet of heating surface, are recommended for drier shown in figure 1, *A*, and for a working steam pressure of 100 pounds gage, and 10 units with 380 square feet for a steam pressure of 60 pounds gage. For drier shown in figures 2, *B* and 1, *C*, 12 units with 456 square feet of heating surface are recommended for a working steam pressure of 100 pounds gage. These units can be constructed as shown in figures 16 and 17 by any competent welder,

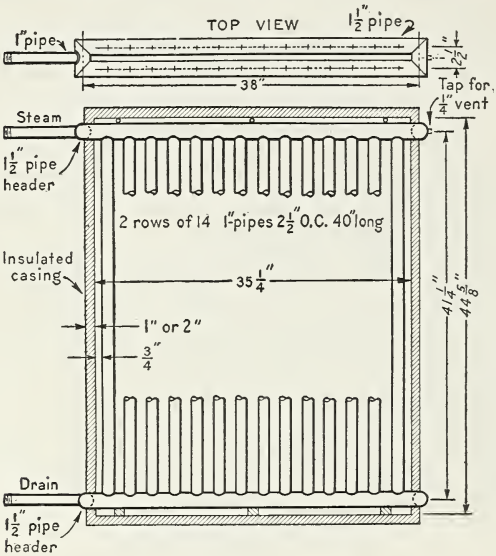

FIGURE 16.—Welded iron-pipe unit for heater for seed-cotton drier. (The top and sides of the insulated casing are built on after the units are assembled.)

and are simple, durable, and effective. Center distances and pipe spacings are alike for all banks of pipe, so that the heater may be cleaned from the sides and the front or back without difficulty. The casing for this heater may be made of 2- by 8-inch dressed lumber and covered with galvanized iron, after assembly of the two-bank

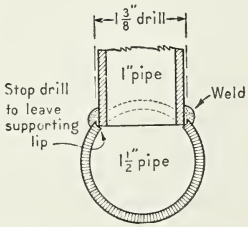

FIGURE 17.—Welded joint where heating pipe joins header.

units. It should be close enough to the outside heating elements to prevent air blowing past without being heated. A side opening in the casing to permit cleaning the pipes is desirable. After the units are assembled a covering of galvanized sheet metal is nailed on snugly to prevent leakage of hot air.

It is advisable in iron-pipe heaters for use with seed-cotton driers to aline the pipes in straight rows both crosswise and lengthwise of the heater to permit ready cleaning and inspection. Staggering of pipes is especially objectionable in heaters for cotton driers because then the second as well as the first row becomes rather quickly covered with an insulating layer of lint, oil, dirt, and other foreign matter which destroys the efficiency of the heating surfaces. The staggering of the pipes also prevent access to all pipes behind the second row. The effectiveness of iron-pipe heaters is not appreciably improved by staggering the rows of pipes.

The approximate performance that may be expected with these units is shown in table 4, compiled from published data of heater manufacturers. Observations made on the performance of the welded heater coils shown in figure 12 have indicated responses to the variations in temperature of the entering air and in the steam pressure approximating those shown by factory-built iron-pipe heaters.

Fin-Type Heaters

With drier shown in figure 1, fin-type heaters instead of iron-pipe heaters may be used if they are properly screened so they do not have to handle air that is heavily charged with dust and other foreign matter. They are not suitable for use with systems employing the exhaust of the cotton unloading fan for drying cotton.

Table 4.—*Average effectiveness of factory-built iron-pipe heaters, open-area type, of 1-inch pipes spaced 2⅝ inches on centers, with air entering at 60° F. and flowing through heater at 800 feet per minute* [1]

Steam		Temperature of air leaving heater		
Gage pressure (pounds)	Temperature	16 banks of pipes	20 banks of pipes	24 banks of pipes
	° F.	° F.	° F.	° F.
40	286.7	165	181	194
60	307.3	175	193	206
80	323.9	185	203	218
100	337.9	193	211	227

[1] This table may be used also for the heater shown in figure 16.

Fin-type heaters, usually made of copper tubes with helical fins, can be purchased and installed for approximately the same cost as equivalent-capacity iron-pipe heaters. Two factory-made heaters of this type, one having vertical tubes and the other having horizontal tubes, are shown in figure 18.

One bank of fin tubing is generally considered to be as effective as four banks of 1-inch iron pipe in heater frames of the same cross section. Purchase specifications therefore should allow one row of fin tubing for each four rows of iron pipe indicated in table 4, for approximately the same gross face area and the same air velocity through the heater.

Because fin heaters are difficult to clean, they must be protected with fine screen, the net free area of which should be slightly greater than the gross face area of the heater. It is recommended that 16-

mesh window screen supported upon heavier hardware cloth be used with these heaters for cotton drying.

LOCATION OF HEATER

The heater for the cotton drier should be located above the water line of the steam boiler and as close to the separator and the top of the drying tower as possible. The resistance imposed by the check valve in the drain line from the heater requires a head of at least 2 feet in order that the condensation shall flow freely through the check valve. It is therefore necessary that the heater be 2 feet or more above the water line of the boiler; the circulation is improved as the distance above the water line is increased. Traps and pumps are seldom

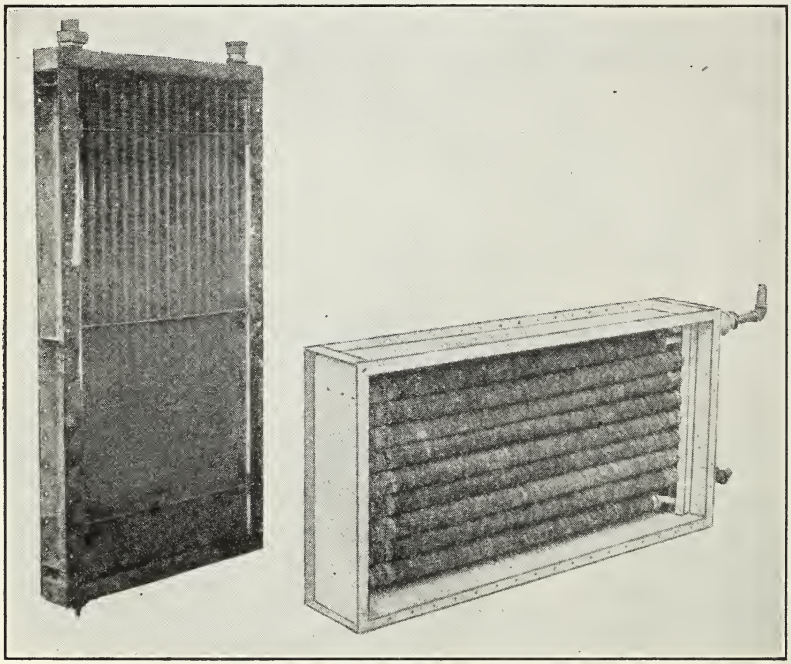

FIGURE 18.—Factory-built fin-type heaters suitable for most cotton driers.

necessary where a gravity return system has been properly installed.

Placing the heater close to the top of the drying tower shortens the hot pipe between the damp-cotton inlet and the top of the tower, and thus reduces the loss of heat and the consequent drop in temperature of the heated air conveying the cotton through the drier.

VALVES AND PIPING

The individual units or sections of heaters may be controlled by separate valves, or the entire heater may be regulated by single supply and return valves. Although better control is obtained by the former system, very satisfactory results have been obtained from the use of single valves.

Manually controlled valves are in general use in cotton-drying installations. For a heater upon a platform above the ginning or operating floor, extension handles or reach rods may be readily installed on manually controlled valves.

Swing joints, properly made, are preferable to rigid piping connections between the headers and the heater. The steam supply or steam header pipe is usually 2½ inches in diameter, the condensation drain or return header pipe should be 1¼ inches in diameter, and the air vent or vent header should be of ½-inch pipe if an automatic thermostatic air-vent valve is to be used.

The high-pressure and low-pressure forms of piping connections for welded iron-pipe units shown in figure 19 may be applied with slight modifications to return-bend coils or to fin-type heaters. Air-vent piping is not shown on this diagram, but should be installed to prevent the heater from becoming air-bound. All piping between the boiler and the heater should be covered.

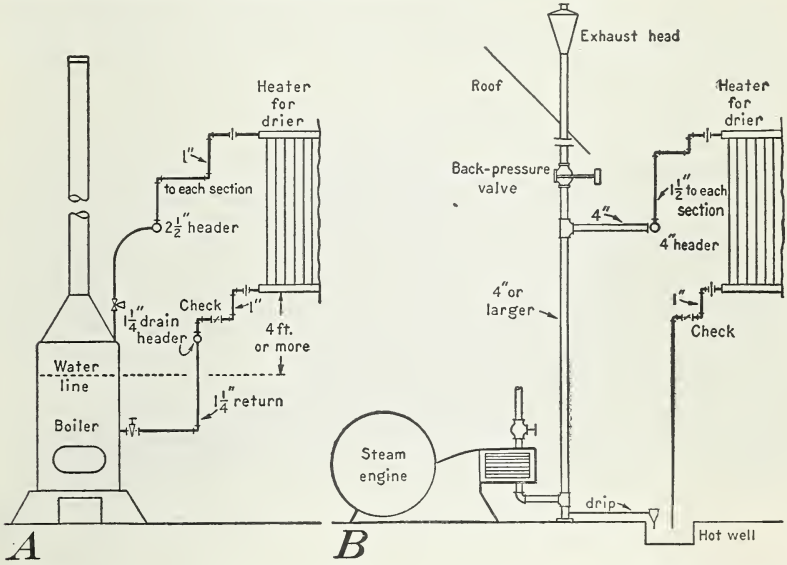

FIGURE 19.—Steam supply and drain piping for heaters for seed-cotton driers: *A*, High-pressure steam supply, suitable for ginning plants powered by electric motors or Diesel engines; *B*, low-pressure steam supply from engine exhaust, suitable for ginning plants powered by steam engines.

A combination of high-pressure and low-pressure piping to the heating units may be readily accomplished where there is insufficient exhaust steam to supply the entire heater. Two or more banks of pipes may be supplied with the high-pressure steam independently, the remaining units being connected only to the exhaust steam. Such an installation should not materially overload the boiler and is more economical than the use of high-pressure steam alone.

Variation of the steam pressure between 50 and 100 pounds will not hinder nor appreciably affect the drying operations if temperatures in the drier are controlled by regulation of the steam-supply valve. It is desirable to maintain a constant temperature during operation.

STEAM-BOILER ACCESSORIES

Injectors and Feed Pumps

Steam boilers used only for drying purposes should be provided with means for supplying make-up of feed water. Injectors frequently are supplied with small boilers, but sometimes at critical periods they are difficult to operate and they are not suitable for returning hot water from the heater of the drier to the boiler unless a gravity return system is installed.

Regular high-pressure piston-packed feed pumps with single steam and water cylinders of the dimensions specified in table 5 are recommended. An air chamber is advisable on the pump discharge to eliminate water hammer. Where the heater cannot be installed above the boiler water line, it may be feasible to drain the hot condensate through a steam trap into a barrel set on a level slightly above that of the pump. If this is done, a gravity flow into the pump suction will allow the pump to return the hot water to the boiler and thus effect a saving of fuel over that required when the steam and condensate are wasted.

Fuel-Oil Burners

Where electricity is available for a cotton drier, motor-driven oil burners may be used, but where electricity is not available or is too costly an oil burner of the steam-atomizing type may be used. Most ginning plants that are not electrically driven have facilities for storing compressed air to start the engines. Compressed air can be used with many forms of steam-atomizing burners in starting the boiler before steam is available. Some ginners fire up their boilers with wood and then cut over to oil when sufficient steam pressure has been generated.

Table 5.—*Approximate minimum sizes of boiler feed pumps recommended for use with 30-horsepower steam boilers*

Item	Diameter of steam cylinder	Diameter of water cylinder	Stroke of pump	Size of steam pipe	Size of exhaust pipe	Size of suction pipe	Size of delivery pipe
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
With gravity return from heater to boiler [1]	2½	1⅜	2	¼	⅜	¾	½
Without gravity return from heater to boiler [2]	3	1¾	2½	⅜	½	1	¾

[1] Capacity of pump 0.013 gallon per stroke, for make-up water only.
[2] Capacity of pump 0.026 gallon per stroke, for all water used by boiler.

The use of inexpensive fuel-oil burners that heat the oil in the burner body and then mix it with the steam at a special tip, is generally restricted to the better grades of fuel oil used in the oil engines of cotton gins. If the same oil can be used for both engine and boiler, the boiler burner may be supplied by a small drum placed upon a frame of its own and filled at intervals from the main supply.

Thermometers

An inexpensive form of satisfactory thermometer for cotton driers is the straight or the angle mercury thermometer (fig. 20) used for steam and hot water, having protected bulb and threaded metal stem. The scale should be approximately 40° to 240° F. A more expensive kind of thermometer has flexible tubing and dial (fig. 20) so that the dial may be at some distance from the bulb. The range of such thermometers is from 40° to 220° or greater.

The thermometer should preferably be located where no seed cotton will strike its stem and thus cause vibration or breakage. When only one thermometer is employed, it should measure the temperature of the air entering the drying tower, because this temperature must be controlled within the prescribed limits of the Government process. Location between the heater and the drier separator (fig. 1, *A*) does

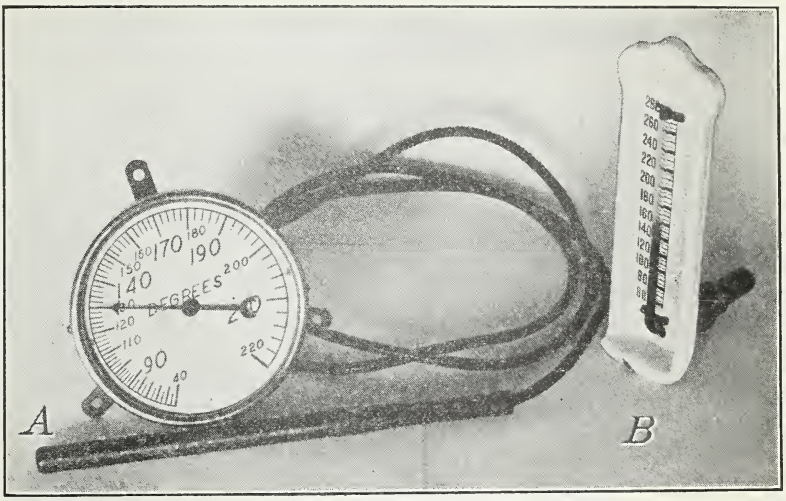

Figure 20.—Thermometers for cotton driers: *A*, Dial and bulb connected by flexible stem; *B*, mercury bulb in threaded metal stem, angle pattern.

this satisfactorily; in model B the thermometer should be placed between the heater and the fan (fig. 2, *B*). Attempts to regulate the drier by means of thermometers placed at the drier outlet have been unsatisfactory because the variable quantities of moisture in the seed cotton produce widely different final temperatures of the moisture-laden air.

OPERATION OF THE VERTICAL DRIER

Before beginning the season's operation, a test run should be made to determine that sufficient air is blown through the drier to convey the cotton readily. Before commencing a day's run, it is advisable to operate the drying fan for at least 5 minutes so that the tower will be

heated and ready to receive the first load of cotton. The piping should be connected during this warming-up of the drier, so that all piping between the drier and the ginning system is warm when drying begins.

All heater screens should be cleaned daily. If this is not done the quantity of air will be reduced to a point where the drier will not operate satisfactorily.

The most effective rate of feeding the drier is that which will supply the gin stands yet avoid an accumulation of surplus seed cotton at the overflow of the distributor, because this surplus may again become damp and because it requires additional expenditure of labor and power for rehandling.

It is well to inspect incoming loads of seed cotton, and adjust drying temperatures to the individual requirements of each load. This can be easily accomplished with a little practice, and will aid in obtaining economical drying and ginning.

SEED-COTTON DRYING AND COTTONSEED STERILIZATION

The cotton-ginning plant equipped with a drier can be equipped on short notice to combat seed infestation. Effective seed sterilization is being accomplished in Arizona, New Mexico, and Texas by discharging jets of live steam into steam-jacketed spiral or screw distributors. A period of sterilization so that the seed will be heated to 150° F. for 30 seconds is specified for pink bollworm infestations of cottonseed (*9*). The capacities of most steam boilers for cotton drying are generally ample for sterilizing up to 2½ tons of cottonseed per hour if no drying is attempted at the same time. Approximately 30 boiler horsepower is an average rating for standard vertical seed-cotton drier installations, and thus will be adequate for the sterilizing outfits in Texas, New Mexico, and Arizona of which few are rated at more than 20-boiler horsepower.

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